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Archaeological sediments from settlement mounds of the Sagzabad Cluster, central Iran: Human-induced deposition on an arid alluvial plain

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ABSTRACT

We outline results of a pilot geoarchaeological study of three settlement mounds (*tepe*) in the Qazvin Plain, near Tehran (ca. 7350 to 2450 cal BP), conducted as part of a wider investigation of the interaction between prehistoric human communities and their environments in western Iran. The aim of the geoarchaeological study was to assess the potential of settlement sediments as records of past human practices and to guide future systematic sampling for geoarchaeological analyses. Here, we integrate bulk sediment (sediment texture, organic matter) with thin section-based (thin section micromorphology, SEM) analyses in order to characterize human inputs in settlement deposits and infer human practices that drove sediment deposition. Plinth degradation and various kinds of burning byproducts and domestic and manufacturing waste furnished distinctive inputs to settlement sediments. Different types of fuel (wood – perhaps *Tamarix*, straw, dung) may reflect diverse domestic and manufacturing contexts of fire use.

1. Introduction

The foothills of the Alborz and Zagros mountain ranges, on the western fringes of the Iranian Plateau, are dotted with numerous ancient settlements, some of which date back to the very dawn of Iran's Neolithic (Majidzadeh, 1976) (Fig. 1). Systematic archaeological research on the Iranian Plateau in the last decade has established ^{14}C-controlled histories of settlement emergence and abandonment, from Early Neolithic villages ca. 8000 BP to the present (Coningham et al., 2004; Fazeli et al., 2005, 2009; Pollard et al., 2012).

Research on the environmental archaeology of the Iranian Plateau has employed various methodological approaches, from zooarchaeology and taphonomy to seismic archaeology and alluvial geoarchaeology (Berberian and Yeats, 1999, 2001; Mashkour et al., 1999; Bocherens et al., 2000, 2001; Schmidt and Fazeli, 2007; Fazeli et al., 2009; Quigley et al., 2011; Schmidt et al., 2011; Maghsoudi et al., 2013). However, high-resolution sediment analyses, a common method of prehistoric settlement research in other Middle Eastern settings (c.f. Matthews et al., 1997), have so far been limited in the Iranian Plateau. Initial attempts include the geoarchaeology and taphonomy of plant remains at the settlement mound of Sheikh-e Abad (Matthews, 2010) and the landscapes and habitation practices in the Late Neolithic to Transitional Chalcolithic village of Tepe Sialk, further south (Kourampas et al., 2013).

Recently obtained radiocarbon chronologies make evident that, on the long term, the western fringes of the Iranian Plateau went through phases of settlement aggregation, abandonment and dispersal (Fazeli et al., 2009; Pollard et al., 2012). The causal links between these settlement histories and economic practices, ecological conditions, human demographics and sociopolitical change, themes central to the Middle Eastern archaeological/historical enquiry, remain poorly understood.

The settlement mounds (*tepe*) of Zagheh, Ghabristan and Sagzabad, situated within 2 km of each other on the Qazvin Plain (Sagzabad Cluster, about 100 km west of Tehran: Fig. 1b), have been the focus of archaeological research by the University of Tehran for the last four decades (Fazeli et al., 2005). Excavation of the Sagzabad Cluster was instigated in the early 1970s by E.O. Negahban (1977) and later, since the 1990s, resumed by other archaeologists (Berberian and Yeats, 1999, 2001; Mashkour et al., 1999; Bocherens et al., 2000, 2001; Coningham et al., 2004; Fazeli and Abbasnejad

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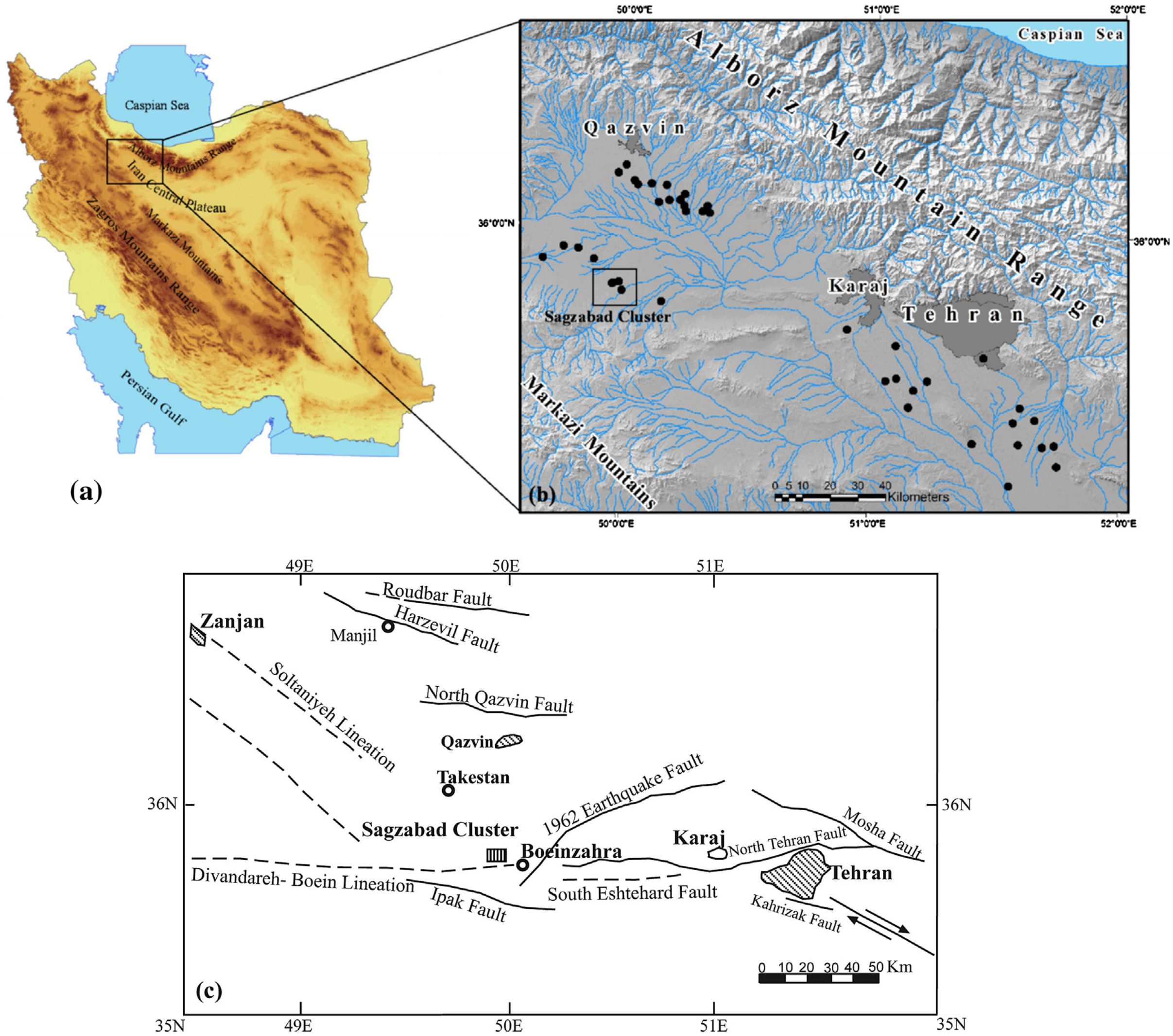

Fig. 1. a) Location of Qazvin Plain in western Iran. b) Topography and drainage around the Sagzabad Cluster. c) Active faults in the Qazvin and Tehran Plains (Zare, 2002).

Sereshti, 2005; Schmidt and Fazeli, 2007; Fazeli et al., 2009; Quigley et al., 2011; Schmidt et al., 2011). The three settlements of the Sagzabad Cluster, record close to 5000 years of settlement aggregation and abandonment in an arid landscape, from the Chalcolithic (ca. 7320 BP: Zagheh) to the Achaemenid Period (ca. 2500 BP: Sagzabad) (Fazeli et al., 2005, 2009; Pollard et al., 2012).

This paper stems from a pilot geoarchaeological study, conducted as part of a wider investigation of the interaction between past human societies and their environments in Western Iran. This pilot study aimed to, 1) asses the archaeological potential of high-resolution sediment analyses at Iranian sites, 2) characterize human inputs in settlement sediments and, 3) guide systematic sampling of these sediments for future work. Here, we outline the environmental (sedimentary and landscape) context of the Sagzabad Cluster (Fig. 1b), characterize archaeological sediments sampled in the course of the pilot study, and infer human practices from their sedimentary footprint.

2. Study area

2.1. Physical setting and climate

The Iranian Plateau is a tectonically active depression, bounded on the north by the Alborz and Kopeh Dagh deformed zones, adjacent to the Turanian Platform, and on the south by the Zagros fold-thrust belt and the Makran accretionary wedge, adjacent to the Arabian platform (Berberian and Yeats, 2001). The three settlements that form the focus of this study are located on the western margins of the Iranian Plateau, on the foothills of the Markazi Mountains. Local bedrock comprises Eocene to Quaternary igneous (volcanic and plutonic), pyroclastic and sedimentary lithologies (predominantly carbonates), drained by the Hajiarab and Khar Roud rivers and their tributaries.

The three settlements of the Sagzabad Cluster are situated on the toes of the Hajiarab fan, where sediment deposition and (localized) channel erosion is controlled by a network of fan-feeding braided streams. This geomorphic setting provided ancient settlers with dependable water resources (not only surface but also – and significantly in such an arid location – groundwater), fine grained sediments for plinth and pottery making, soils for cereal cultivation and proximity to the Merkazi uplands with their woods and pastureland for animal grazing. At the same time, this fan-toe setting presented ancient settlers with risks: flash flooding, channel erosion and, at the tectonically active Merkazi mountain front, earthquakes. As many other ancient settlements in Iran, therefore (c.f. Schmidt et al., 2011), the location of the Sagzabad Cluster represents a tradeoff between episodic risk and regular affordances.

In this setting, changes in discharge, flow velocity, sediment yield and the configuration of braided drainage (through channel migration and shifts in braiding pattern: Rachocki, 1981; Field, 2001; Nichols, 2005; Weissmann et al., 2005) produced sediments of contrasting, high and low-energy textures. Schmidt et al. (2011) divided the area's Quaternary stratigraphy into three main depositional units (Fig. 2). The oldest recognized alluvia (Q3), of Late Pleistocene age, are now subjected to active incision at the Hajiarab fanhead. These deposits consist of coarsely bedded, moderately sorted, strongly imbricated conglomerates and sandstones, deposited by unconfined, high-energy sheetflows. Later alluvia (Q2 – subdivided to a number of higher-order units: Fig. 2), consist of interbedded silt, gravel and loams, fining into silts and clays basinwards. These sediments were also deposited by sheet flows. Q2 deposits were subsequently incised by an intricate network of channels whose sediment fill constitutes the youngest alluvial unit, Q1 (Schmidt et al., 2011).

Mid to late Holocene channel migration and alluvial sedimentation had marked impacts on settlement preservation. High-energy fluvial channels caused localised erosion of settlement mounds, whereas low-energy, mainly overbank deposition provided conditions of optimum preservation through settlement burial.

In the tectonically active Iranian Plateau, alluvial fan sedimentation is closely implicated with faulting. A number of active faults have been mapped in the Qazvin Plain, including the Ipak Fault, a branch of which caused the catastrophic Ms 7.2 Boeinzahra Earthquake in 09.01.1962 (Berberian, and Yeats, 1999: Fig. 1c).

The present climate of the Qazvin Plain is arid to semiarid, with mean annual temperature of 14.3 °C and mean annual precipitation of 317.3 mm/y. The monthly distribution of temperature and precipitation conforms to a Mediterranean climatic regime, with most of the rainfall in the cooler, winter months (Iran Meteorological Organization, 1965–2005 localised).

The Late Pleistocene and early Holocene climates of western Iran have been the subject of research since the early 1960s (Hutchinson and Cowgill, 1963; Van Zeist and Wright, 1963; Wright, 1963; Megard, 1967; Wasylikowa, 1967; Krinsley, 1972; Van Zeist and Bottema, 1977; Stevens et al., 2001; Kehl et al., 2005; Wasylikowa, 2005; Kennett and Kennett, 2006; Kehl et al., 2009; Riehl et al., 2009; Karimi et al., 2011; Khormali and Kehl, 2011). Multiproxy reconstructions of earlier Holocene climates suggest that the Qazvin Plain was moister during the Late Neolithic–Transitional Chalcolithic. Kehl et al. (2009) and Schmidt et al. (2011) infer an increasingly moister Holocene climate after c. 7200 BP. By affording more water resources, this moist climate may have encouraged initial settlement at Zagheh, on the Hajiarab alluvial fan. The suggestion of Late Neolithic–Transitional Chalcolithic humidity is also supported by the climatic record of Lake Zeribad, on the Zagros Mountains (Stevens et al., 2001), and by paleosols in Persepolis, South Iran (Kehl et al., 2005).

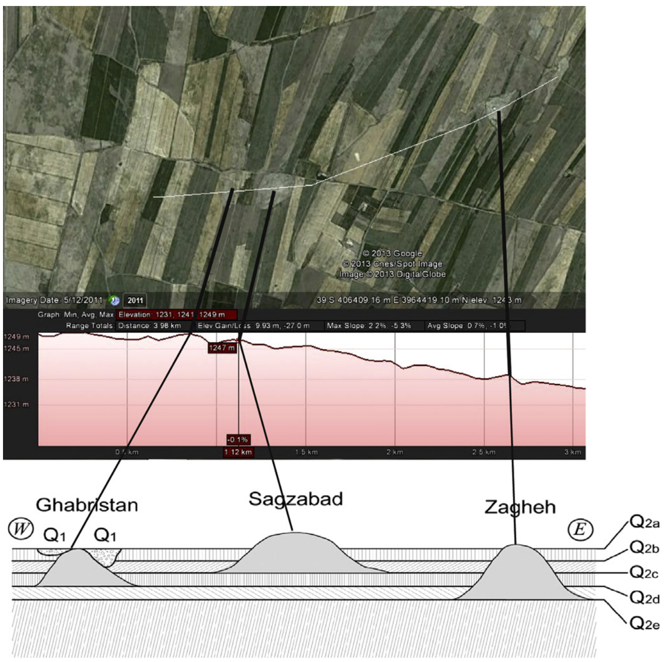

Fig. 2. Schematic alluvial stratigraphy around the Sagzabad Cluster tells (Schmidt et al., 2011: p. 585) and cross section from Gabristan (West) to Zagheh (East). Q1: Post-occupation channel fill; Q2e to Q2a: Holocene alluvia, and interbedded settlement deposits.

2.2. Chronology and archaeological record

Archaeological studies in the Qazvin Plain provide invaluable information about Iran's sedentary communities from the eighth millennium BP onward. Radiocarbon chronologies (Fazeli et al., 2005, 2009; Molla Salehi et al., 2006; Pollard et al., 2012) indicate that no single site of the Sagzabad Cluster spans the entire period of occupation from the Neolithic to the Iron Age (Table 1). The three Sagzabad Cluster settlements were occupied in succession: Zagheh was the earliest (from 7320 to 7020 cal BP: Transitional Chalcolithic), followed by Ghabristan (from 6150 to 5450 cal BP: Early, Middle and Late Chalcolithic); then by the Late Bronze to Iron Age Sagzabad (from 3730 cal BP to the Achaemenid period, ca. 2500 BP). A ca. 1700–1600 years gap in human settlement is, therefore, inferred between the abandonment of Ghabristan and the settlement of Sagzabad in the Late Bronze Age (Pollard et al., 2012). So far, there is no cultural evidence for the Early and Middle Bronze Age within the region, whereas the Late Bronze Age and Iron Age are widespread (Table 1). This succession of settlements gave rise to the complex stratigraphy of settlement and alluvial deposits outlined in Fig. 2.

Table 1
Comparative chronology of the Qazvin plain, based on evidence from the excavated sites (Fazeli et al., 2009).

Period BP		The Qazvin plain
Bronze Age		Sagzabad
Late Chalcolithic 5650–5350		Ghabristan III–IV
Middle Chalcolithic 5950–5650		Ghabristan II
Early Chalcolithic 6250–5950		Ghabristan I
Transitional Chalcolithic	Late 6550–6250	
	Early 7150–6550	Zagheh
Late Neolithic (7550–7150)		

For the inhabitants of the Qazvin plain, the seventh millennium BP (7150–5950 cal BP) was a period of accelerated socioeconomic change, marked by agricultural intensification, increasing social complexity, change in ritual activities, long distance trade and growing craft specialization. Palaeobotanical studies show that the inhabitants of Transitional Chalcolithic Zagheh resorted to a mixed economy of farming, animal husbandry (cattle, sheep and goat were fully domesticated by the Transitional Chalcolithic: Mashkour et al., 1999), and exploitation of wild resources (Fazeli et al., 2009). Tepe Zagheh is one of Iran's earliest sites with evidence for craft

activities, dating back to the first half of the seventh millennium BP. The southern part of Tepe Zagheh is remarkably different from other sections of the site, with 5.05 m of ashy layers associated with ceramic production. At Zagheh, people were buried inside the village both in the workshop areas and in the residential section (Malek Shahmirzadi, 1977). Some burials are associated with modest quantities of ceramic vessels, stone cosmetic palettes and stone beads.

The sixth millennium BP settlement of Tepe Ghabristan contains 6 m of cultural layers mainly related with craft production activities. Earlier excavators recorded a complex of pottery and copper workshops (hearths and crucibles, molds, copper ore) and many copper objects (daggers, axes, chisels, awls, needles, pins, bracelets), which are strikingly similar to artifacts from contemporary levels at other Iranian Plateau settlements, such as Sialk and Hissar (Majidzadeh, 1976, 1979). The Late Chalcolithic of the Qazvin plain can be characterizing by intensified interaction, within the Iranian Plateau and beyond, across the Zagros mountains, to the Mesopotamia (Majidzadeh, 1976, 1979; Fazeli et al., 2013).

3. Materials and methods

Undisturbed sediment samples for thin section micromorphology and elemental analyses were collected in the spring of 2011. Bulk sediment samples for particle size and organic matter analyses were also collected from points next to the micomorphology samples. Sampling strategy was dictated by the exploratory scope of this project, accessibility of the sites and the partial exposure of the stratigraphy. Since there were no recent excavation trenches and earlier trenches were for their most part backfilled, we were unable to obtain comprehensive sample sets from across the archaeological stratigraphy. Instead, we sampled the exposed parts of the earlier excavation trenches, after removal of colluviated sediment from the profile.

Three samples were collected from Zagheh, corresponding to the upper part of the settlement mound. Six samples were collected from Ghabristan, corresponding to both occupational and post-occupational layers. Four samples were obtained from occupational layers of the Sagzabad mound (Fig. 3).

3.1. Thin section micromorphology and elemental analysis

Thin section micromorphology is the study of, "undisturbed soil and regolith samples with microscopic and ultramicroscopic techniques, in order to identify their different constitutions and to determine their mutual relationships, in space and time" (Stoops, 2003: pp. 5). Blocks of undisturbed sediment were air-dried and impregnated with polyester resin under desiccation vacuum. Thin

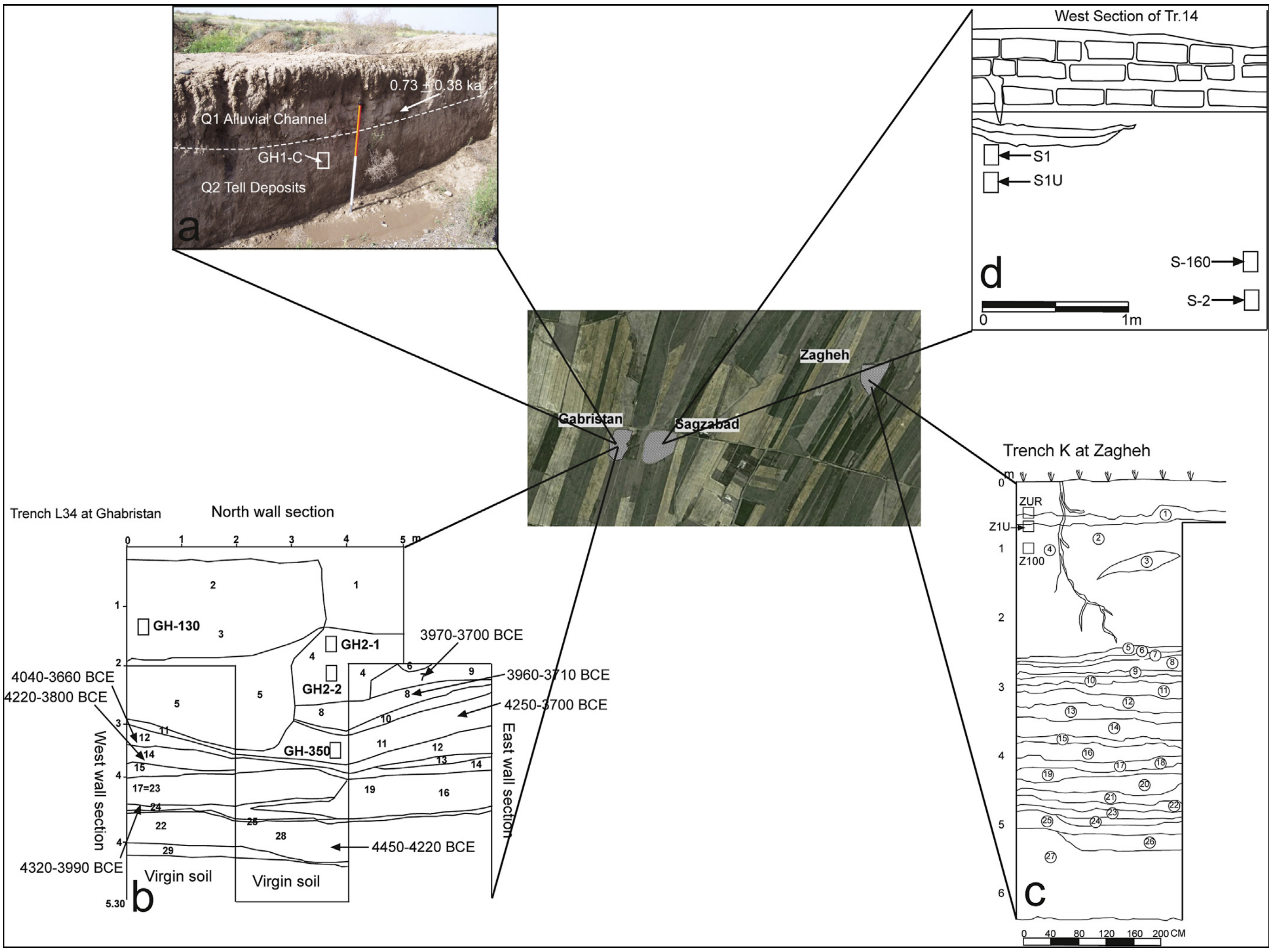

Fig. 3. Sampled profiles and sediment sample location (rectangles: thin section micromorphology samples). a) Trench GH1 in the southern part Ghabristan Tell (Schmidt et al., 2011). Note the position of sample GH1-C underneath thermoluminescence-dated alluvial channel fill (Q1 alluvium: see Fig. 2). b) Trench L34 at Ghabristan, also showing radiocarbon chronology (after Fazeli et al., 2005), c) Trench K at Zagheh. d) Trench Tr.14 at Sagzabad.

sections (8 × 4 cm; thickness ca. 30 μm) were prepared from these hardened blocks. Thin sections were examined under a polarizing microscope at magnifications of ×10 to ×400 using plain polarised (PPL), cross-polarised (XPL) and oblique incident light (OIL). Section description and interpretation follows Courty et al. (1989), FitzPatrick (1993), Bullock et al. (1985), Stoops (2003), and Stoops et al. (2010).

Quantitative estimates and measurement of charcoal and other features in thin section were made using *analySIS pro5* image analysis software. Elemental analyses of selected micromass areas, sediment particles and pedofeatures were done on uncovered thin sections using an Oxford Instruments SEM system with X-ray analysis capabilities (secondary electron detector) and INCA analytical software (version 4.15). SPSS statistical software was used for the statistical analysis of elemental composition data.

3.2. Textural analysis

Grain size analysis is a means for describing sediment texture; this can often supply clues to the origin, transport, and deposition of sediments (Folk and Ward, 1957; Folk, 1966; Blott and Pye, 2001). Bulk sediment samples were oven-dried overnight at 105 °C and divided into representative subsamples. Samples that contained grains larger than 2 mm in diameter were hand-sieved through the 2000 μm sieve to separate the gravel fraction (Haggar et al., 2002). This fraction was examined under a binocular microscope to identify grain composition and morphology. To disaggregate mineral aggregates, distilled water and the disaggregating agent Calgon (sodium hexametaphosphate) were added and the samples were stirred and shaken for 1 h. Disaggregated sediments in suspension were then subjected to standard grain size analysis (c.f. Goldberg and Macphail, 2006) in a Cutler lazer particle analyzer. Particle population statistics were computed and plotted with the particle analyzer software LS 230 and GRADISTAT version 4.5. Sediment texture was described by means of the following statistical indices: mean grain size; standard deviation (a measure of the degree of sorting of the grain population around the mean); coefficient of variation (CV: the ratio of the standard deviation to the mean – a measure of the dispersion of the grain population distribution); skewness (a measure of the asymmetry of the grain size distribution); and kurtosis (which describes the rate of grain size concentration around the mean).

Table 2
Texture and grain size distribution of the sampled sediments.

Sample	Sample type	Textural group	Skewness	Kurtosis	Mean grain size (μm)	CV
Ghabristan						
GH1	Bimodal, very poorly sorted	Muddy sand	Very fine skewed	Leptokurtic	152.3	75.2
GH1-C	Unimodal, poorly sorted	Mud	Symmetrical	Mesokurtic	8.75	97.95
GH2-1	Bimodal, very poorly sorted	Muddy sand	Fine Skewed	Mesokurtic	91.48	152.9
GH-130	Trimodal, poorly sorted	Sandy mud	Symmetrical	Mesokurtic	53.24	141.7
GH-350	Bimodal, poorly sorted	Sandy mud	Fine skewed	Platykurtic	66.16	128.7
Zagheh						
Z1	Trimodal, very poorly sorted	Muddy sand	Fine skewed	Platykurtic	80.35	124.8
Z1U	Unimodal, poorly sorted	Mud	Symmetrical	Leptokurtic	8.02	99.06
Z-100	Trimodal, very poorly sorted	Muddy sand	Fine skewed	Platykurtic	118	130.9
Sagzabad						
S1	Unimodal, poorly sorted	Mud	Symmetrical	Leptokurtic	8.05	98.94
S2	Unimodal, poorly sorted	Mud	Symmetrical	Leptokurtic	7.23	97.02
S-160	Trimodal, very poorly sorted	Slightly gravelly muddy sand	Symmetrical	Platykurtic	115.1	145.7

3.3. Organic matter (OM) analysis

The OM content of the sediments was measured with the method of loss-on-ignition. Representative subsamples (10–20 g) of air-dried sediment were oven-dried overnight at 105 °C. These samples were then weighted, heated in a furnace at 450 °C for 4.5 h and weighted again. The weight loss of each sample represented its original organic matter content.

4. Results: microfacies and sediment composition

4.1. Tepe Zagheh

Sampled sediments came from Trench K of the early Transitional Chalcolithic settlement (Table 1; Fig. 3). These sediments are grouped into three main facies, each comprising a distinct array of textural and structural attributes and sediment constituents, and representing a distinct nexus of formative processes (c.f. Reading, 1996; Courty, 2001).

4.1.1. Facies Zi: ash layers

This facies is represented by sample Z1, from a macroscopically identified ash layer (Fig. 3). Texturally, it is very poorly sorted clayey sand with trimodal distribution (C.V: 124.8; mean grain size: 80.35 μm: Table 2; Figs. 4 and 5). Sharp and distinct peaks are present in the 5–20 μm grain size range. No micromorphological evidence is available for this facies.

4.1.2. Facies Zii: sandy loams with burning residues

This facies is represented by sample Z-100, from the upper parts of the trench (Fig. 3). Bioturbation by plant roots is intense in these parts. Texturally, this is very poorly sorted, trimodal clayey silty sand (C.V: 130.9; mean grain diameter: 118 μm), indicating admixture of grains with different transport histories (c.f. Lewis et al., 2012; Table 2, Figs. 4 and 5).

Thin sections exhibit moderately homogenous, rubified and locally ash-rich micromass, with double space porphyric c/f-related distribution and channel microstructure (Table 3). Voids and channels with pelletal fill (1000–5600 μm) are abundant (10–20%). These have resulted from intense burrowing by invertebrate soil fauna (Fig. 7h). Sample Z-100 is the most intensely bioturbated sample in the sample set.

Human inputs comprise some wood charcoal, other plant residues (rare), brown and yellowish (unburned) excrement (Fig. 7i), burned particles of amorphous organic composition and abundant

Table 3
Summary thin section micromorphology of Sagzabad Cluster sediments. Frequency class refers to the appropriate area of section (Bullock et al., 1985), ○, Very few; ○○, few; ○○○, Frequent/common; ○○○○, Dominant/very dominant.

Thin section	Fine mineral material (<63 Mm)		Coarse organic										
			Component (>63 Mm)										
	Nature of fine mineral material (PPL)	Birefringence Fabric (XPL)	Plant tissues (slight/moderate decomposition)	Charcoal	Tissue residue	Bone (unburnt)	Bone (burnt)	Shell fragment	Plant mouldic pores	Desiccated plant	Excrement	Coprolite (carnivorous/ omnivorous)	Fresh roots
GH1-C	Light Grey 10YR71	Anisotropic calcite crystalitic		○○○		○		○○					○
	Dark Yellowish Brown 10YR46 Yellowish Brown 10YR58												
Gh2-1	Light bluish grey GLEY275PB	Anisotropic speckled B-fabric		○○○○		○	○	○○	○				
	Brownish yellow 10YR68 Gray/Pale Brown 10YR62												
Gh2-2	Light bluish grey GLEY275PB	Anisotropic speckled B-fabric		○○○○		○		○○	○				
	Light Yellowish Brown 10YR64 Light Brownish Grey 10YR62												
Gh- 350	Light Grey 10YR71	Anisotropic	○○	○○○○	○○	○		○	○○		○		
	Yellowish brown 10YR58 Dark yellowish brown 10YR46												
Z-100	Grey 10YR61	Anisotropic crystalitic	○	○○		○○		○○○	○○		○○○○		
	Brown 10YR43 Dark Yellowish Brown 10YR36												
Z1U	Light yellowish Brown 10YR64	Anisotropic crystalitic		○	○○	○		○	○○				
	Yellowish Brown 10YR56 Dark Yellowish Brown 10YR46												
ZUR	Yellowish brown 10YR56	Anisotropic crystalitic	○	○	○○			○	○○				
	Dark Yellowish Brown 10YR46 Brownish Yellow 10YR68												
S1	Yellowish Brown 10YR56	Anisotropic crystalitic	○○	○○○		○		○○○	○				
	Brownish Yellow 10YR66 Blush Grey GLEY2510B												
S1U	Light Yellowish brown 10YR64	Anisotropic	○	○○		○○		○○	○○			○	
S- 160	Brownish Yellow 10YR66	Anisotropic	○○○	○○○○		○○		○○	○○	○○○○	○	○○	
	Dark Yellowish Brown 10YR46 Yellowish Brown 10YR56												
S2	Pale brown 10YR63	Anisotropic	○○	○○○		○○○	○	○○○	○○○○		○	○	
	Dark Yellowish Brown 10YR46 Yellowish brown 10YR56												

shell and bone fragments of diverse sizes. Rubified particles of various sizes are also abundant (Fig. 7j and k). Some of these particles contain straw-mouldic pores and are, interpreted as burned mortar, bricks or ceramics. One particle with vesicular structure is interpreted as slag. Organic matter is very high in this sample, perhaps due to the additional contribution of post-depositional root and faunal inclusions. In addition to intense bioturbation, postdepositional features include abundant iron nodules (79–114 μm), iron impregnation (rare) and rare calcite coatings and hypocoatings.

This markedly heterogeneous sediment appears to have resulted from accumulation of ash and other burning byproducts, including abundant byproducts of brick or ceramic making. This interpretation is consisted with the location of the sample in the part of the settlement thought to have accommodated pottery making and other craft activities (Fazeli et al., 2005). Abundant bone fragments may have resulted from a related manufacturing practice, or from domestic waste, suggesting the close juxtaposition of craft and domestic practices in the Transitional Chalcolithic village. Extensive sesquioxide translocation postdepositionaly is

Fine organic Component (<63 Mm)			Other inclusion	Pedofeatures						Structure		
Organic fine material (black)	Amorphous (reddish brown)	Amorphous (yellow)	Rubified mineral (OIL)	Fe impregnation	Infilling	Calcite rim	Fe Coating	Fe nodules (Xpl)	Calcite coating and hypocoating	Microstructure	Coarse mineral arrangement	Coarse/fine related distribution
		○○	○○	○	○	○○	○	○○○	○○	Channel; partly massive with simple voids,	Muddy, homogenous groundmass poorly sorted to moderately sorted	Open porphyric
			○○○	○	○			○○○	○○○○	Massive; partly channel, dominant voids are channels and chamber,	Muddy sand, heterogeneous groundmass, poorly to very poorly sorted	Open porphyric
			○○○	○○	○○	○		○○○	○○○	Massive; occasionally channel, occasional circular or elongated pores,	Muddy sand, heterogeneous but partly homogenous groundmass, Poorly to moderately sorted	Open porphyric
			○○○	○	○			○○	○○	Massive; partly channel, dominant voids are channels and chambers,	Sandy mud, moderately heterogeneous groundmass, moderately to poorly sorted,	Open porphyric
○○			○○○○		○○○○			○○○	○○	Channel; dominant voids are channels and infilled channels,	Muddy sand, moderately homogenous groundmass, poorly to very poorly sorted,	Double space porphyric
		○	○	○			○○	○○	○○	Massive with some voids, in top angulary blocky structure,	Muddy, homogenous groundmass, moderately to poorly sorted,	Open porphyric
			○○						○○○	Vesicles; occasionally fissure,	Muddy, homogenous groundmass, moderately to poorly sorted,	Open porphyric
			○○○○			○		○○	○	Massive; occasionally some fissures and channels,	Muddy, moderately homogenous groundmass, moderately to poorly sorted,	Open porphyric
		○	○○○	○	○	○		○○○	○	Massive; occasionally some fissures and channels,	Muddy sand, moderately homogenous groundmass, moderately to poorly sorted,	Open porphyric
	○○	○	○○○○		○		○	○○		Massive; occasionally some fissures and channels,	Slightly gravelly muddy sand, heterogonous groundmass, poorly to very poorly sorted,	Open porphyric
			○○○		○			○○	○	Complex; occasionally fissured and channeled,	Muddy sand, heterogeneous groundmass, poorly sorted, to very poorly sorted,	Double space to open porphyric

consistent with the geomorphological setting of the site (level off with the surrounding land surface: Fig. 2) and immersion of the sediment to seasonally fluctuating groundwater.

4.1.3. *Facies Ziii: muddy loams with straw moulds*

This facies is represented by samples ZUR and ZU1 (Fig. 3). Texturally, it is poorly sorted unimodal silty clay (CV: 99.06; mean grain diameter: 8.02 μm in ZU1), with the attributes of fine-grained sheet flow deposits (Table II, Figs. 4 and 5).

In thin section, facies Ziii comprises massive loam with open porphyric c/f-related distribution and brown groundmass locally (sample Z1U; Table 3). Microstructure is very porous, with numerous vughs, straw moulds and fissures (Fig. 6a); angular blocky microstructure is also present (sample ZU1). Mineral grains are affected by pellicular alteration (scale 1 *sensu* Stoops, 2003). Feldspar grains are replaced with calcite locally.

Human inputs are markedly rare in this facies, the lowest in the Sagzabad Cluster sample set. These include a few charcoal particles,

plant tissue and tissue residues, and very rare shell and bone fragments and rubified particles. Sample Z1U also contains rare amorphous organic/phosphatic particles with straw-mouldic pores. These may have resulted from fecal material, perhaps herbivore dung (?). Postdepositional pedofeatures include anorthic iron oxide nodules, coatings and diffuse impregnations (abundant in sample Z1U, where they give the groundmass its distinctive brown colour), calcite hypocoatings and gypsum infillings with mammillate edges.

These muddy, inclusion-poor, porous sediments resulted from the collapse of plinth masonry. The textural aspect of this facies may indicate that Zagheh's inhabitants sourced their building materials from fine-grained sheet flow deposits of the intrachannel flats, in the immediate environment of the village. These plinth deposits, therefore, also reflect the location of Zagheh in the distal, apex zone of the Hajiarab alluvial fan, where Holocene deposits are predominantly fine grained. Iron oxide, calcitic and gypsum pedofeatures evidence seasonal wetting and drying in this part of Qazvin plain, congruent with the arid/semiarid regional climate.

4.2. Tepe Ghabristan

The sampled profile is Trench L14, on the western part of Tepe Ghabristan (Fig. 3). Post-occupation deposits are represented by the fill of a 5.9 m wide, ca. 0.7 m deep channel incised in settlement deposits (Fig. 3). This sediment has returned an OSL age estimate of ca. 730 cal BP (Schmidt et al., 2011). Underneath this come about 3 m of archaeological layers. Most samples from Ghabristan date to the Middle Chalcolithic. Sample GHC-1 dates to the Late Chalcolithic (5650–5350cal BP). Tepe Ghabristan deposits are grouped into three facies.

4.2.1. Facies GHi: post-occupation channel fill

This sediment is relatively well sorted muddy sand (mean grain size: 152 μm), devoid of particles coarser than 2 mm. Grain distribution is markedly bimodal, indicating admixture of grain populations contributed by various transport and depositional processes (c.f. Lewis et al., 2012), perhaps including reworking of anthoropogenic deposits (see below; Table 2; Figs. 4 and 5). No micromorphological evidence is available for this facies:

4.2.2. Facies GHii: muddy loam with rare human inputs

This facies is represented by sample GH1-C, located a few centimeters underneath the post-occupation deposits described above. Texturally, Facies GHii is poorly sorted unimodal sandy silty clay (CV: 98; mean grain size: 8.75 μm; Table 2; Figs. 4 and 5).

Thin sections show muddy, moderately homogenous groundmass with open porphyric c/f-related distribution. Microstructure is massive, with partly infilled bioturbation channels, some of which contain decomposing rootlets (consistent with the near-surface location of the sample). Mineral grains are mainly well rounded. Many mineral grains are affected by pelicular alteration (class 2 *sensu* Stoops, 2003: Fig. 7a).

Human inputs (charcoal and other burned plant tissue, amorphous burning residues, shell and bone fragments, amorphous phosphatic/organic particles) are the lowest in the Tepe Ghabristan sample set. Some of the rubified particles contain straw-mouldic pores, suggesting that these probably originated in straw-tempered masonry elements (e.g. baked mud bricks, or materials exposed to heat during the course of their use, e.g. near hearths or other sites of pyrotechnic activity), or ceramics (c.f. Matthews, 2010; Kourampas et al., 2013). Although plant-shaped voids may also occur in other settlement environments (e.g. street deposits), interpretation of these particles as baked bricks is supported by rubification of their micromass.

Iron oxide enrichment of the clayey micromass, with impregnation spots, hypocoatings and anorthic nodules, suggests cycles of wetting and drying, driven by seasonal water saturation of this part of the site. Calcite rims and hypocoatings are also present, suggesting evaporation deficit post-deposition.

Textural characteristics, grain rounding and relatively low frequency of human inputs suggest that facies GHii was deposited from surface wash processes in the relatively low-energy, fines-dominated alluvial environs of Tepe Ghabristan. This facies may, therefore, represent early post-occupation deposition, resulting from colluviation from the abandoned settlement. Iron oxide pedofeatures reflect the geomorphic setting of this sediment underneath a shallow channel (Fig. 3). These and calcitic pedofeatures are consistent with the arid/semiarid Late Holocene climate of the region.

4.2.3. Facies GHiii: muddy loam with abundant burning residues and gypsum

This facies is represented by samples GH-130, GH2-350, GH2-1 and GH2-2, associated with macroscopically identified ash layers in Trench L14: cm-scale bands of pale grey, fine-grained deposits with a loose, powdery texture that contrasts with that of their surrounding deposits (Fig. 3).

Texturally, facies GHiii comprises poorly to very poorly sorted, heterogeneous sandy mud to clayey sandy silt with bimodal or trimodal grain size distribution (C.V: 128 to 153; mean grain diameter: 53–91 μm; Table 2; Figs. 4 and 5). A sharp peak in grain size between 5 and 30 μm falls within the range typical of ash deposits (5–20 μm: Canti, 2003).

Thin sections of this facies show moderately heterogeneous groundmass and open porphyric c/f-related distribution. Microstructure is massive, with a few channels filled with loose excremental pellets (up to 5–7% in sample GH2-1) and very rare straw moulds (sample GH2-2; Table 3). Calcitic rhombs, probably originating in ash, are present in the groundmass of all samples, locally in high concentrations (e.g. GH2-2). Yellowish groundmass (under OIL) is present in parts of sample GH2-1; this may indicate exposure to high-temperature (Simpson et al., 2003). Quartz and feldspars are abundant in the sand fraction. Many mineral grains, especially feldspars, are altered, with accumulation of iron oxides in fissures and cleavage planes.

Human inputs are the highest in the entire Sagzabad Cluster sample set, with abundant wood charcoal (from 5 to >15%: Table 3), other burned and/or decomposed plant tissue residues, rare shell fragments and burned and unburned bone splinters (Fig. 7f). Rubified particles are also abundant, alongside (rarer) heat-altered mineral grains and possible slag with vesicular structure.

Notable in this facies are various particles that may have resulted from disintegrating human-built structures. In sample GH-350, an angular particle with heat-altered mineral grains set in compacted, opaque, organics-rich matrix may represent some kind of plaster or other surface lining at/near a site of pyrotechnic activity (e.g. trampled floor, mortar, or even some kiln or vessel lining: Fig. 7b). Unburned particles with straw-mouldic pores, attributable to mud plinths, tempered plaster or other masonry remains (c.f. Matthews, 2010; Kourampas et al., 2013), are also common. In sample GH2-2, (rare) burned and compacted – probably trampled – dung-based material may have resulted from disintegration of daub or plaster (Fig. 7e).

The most striking postdepositional pedofeatures are various gypsum neomorphs, reflecting groundwater supersaturation *re* $CaSO4$ (Poch et al., 2010). Gypsum infillings are present mainly in the form of dense cryprocrystalline accumulations that impregnate micromass and replace calcitic ash (sample GH-350; Fig. 7d). Lenticular gypsum is relatively frequent in sample GH2-2, with well

developed, idiomorphic crystals (Fig. 7g). Formation of this type of gypsum may have been favoured by the presence of organic matter in the sediment (Cody, 1979, quoted by Poch et al., 2010).

Calcite rims and hypocoatings around probable rootlet channels are also present (to abundant in sample GH2-1), indicating evaporation deficit. Calcite deposition may have been mediated by soil organisms (Durand et al., 2010). Crystallitic calcite in pores of charcoal particles (e.g. sample GH2-1) may also be neomorphic in origin. Iron oxide nodules, spots and diffuse impregnation of the micromass are present throughout (to relatively abundant: samples GH2-1, GH2-2).

Dusty, silty clay coatings are present – but rare – in bioturbation pores in sample GH3-1, the most intensely bioturbated representative of this facies. The temporal relationship of coatings and calcite and gypsum pedofeatures could not be inferred from this single thin section. In view of the unfilled/uncollapsed state of the accommodating pores, nevertheless, these coatings appear to be relatively recent features. These coatings evidently resulted from episodic (?) percolation of water through the network of sediment pores (Bullock et al., 1985; FitzPatrick, 1993; Stoops, 2003). They are consistent with the geomorphic setting of the site in the floodplain of the Hajiarab River where sheet floods are frequent.

This markedly heterogeneous facies resulted from deposition of diverse burning byproducts and possible masonry remains. Evidently, poor sorting with bimodal or trimodal grain size distribution and distinct peaks in the 5–30 μm range are textural signatures of ash and other burning inputs. Abundant ash and wood charcoal may indicate high-temperature burning. Although the nature and purpose of burning activities cannot be deciphered from sedimentary evidence alone, a domestic context appears unlikely in view of the scarcity of food residues. The very low content of plausible food residues (bone and shell) contrasts facies GHiii from other facies rich in burning byproducts.

Although gypsum pedofeatures are widespread in the arid soils of the Iranian Plateau (Khademi and Mermut, 2003), in the Sagzabad Cluster sample they occur exclusively in this facies. A similar association of neomorphic gypsum with calcitic ash has been noted by researchers of settlement geoarchaeology elsewhere in the Near East (e.g. Shahack-Gross and Finkelstein, 2008). This association may be genetic, reflecting systematic use of particular (wood) fuel: Shahack-Gross and Finkelstein (2008), for instance, have shown that burning of *Tamarix aphylla* results in the formation of gypsum nodules from recrystallization of *Tamarix* ash in the presence of water. Such recrystallisation, which possibly reflects harsher environmental conditions, may be an early postdepositional phenomenon (occurring in days to weeks in laboratory conditions; thus maybe in just one winter season in nature). It is noteworthy that *Tamarix* sp. has been identified as the main fuel at other prehistoric settlements of the Sagzabad Cluster (e.g. Zagheh: Mola Molla Salehi et al., 2006; Shirazi et al., 2006).

4.3. Tepe Sagzabad

Sediment sampling focused on Trench 14, a 9.8 m-deep trench on the southern fringes of Tepe Sagzabad (Fig. 3). This trench exposes fine grained sediments, correlated with Holocene progradation of the Hajiarab fan, down to a depth of 6.6 m (Q2 deposits in the nomenclature of Schmidt et al., 2011). Thin 'cultural' layers are interbedded within these at −1, −2.30 and −3 m. Tepe Sagzabad samples date to the Bronze Age. These sediments are grouped into the following facies:

4.3.1. Facies SZi: muddy loam with burning residues

This facies is represented by samples S1 and S1U, both from the upper parts of Trench 14 (Fig. 3). Texturally, it consists of unimodal, poorly sorted silty clay (C.V. 98.9 to 97.02; mean grain size 8.05 μm–7.23 μm; Table 2, Figs. 4 and 5).

In thin section, Facies SZi is poorly sorted muddy loam with moderately homogenous groundmass and open porphyric c/f-related distribution (Table 3). Microstructure is massive, with occasional fissures and partly filled bioturbation channels (from 5 to 10% in sample S1 to <5% in stratigraphically lower S1U). Straw-mouldic pores are also present (lower part of sample S1). Many of the mineral grains are subrounded to rounded. About 2.5–25% of mineral grains – mainly feldspars – are altered, with pellicular and complex alteration patterns (alteration class 1 *sensu* Stoops, 2003).

Biogenic inputs are common, including wood and fibrous charcoal, derived from herbaceous plants (Miller and Sievers, 2012) – in the investigated context probably grassesstraw and sages (rare in sample S1U), decomposed plant tissues (rare), amorphous organics and relatively abundant fragments of shell (154–1767 μm) and bone (1732–1238 μm). Sample S1U also contains rare particles of a compacted, yellowish, amorphous – probably phosphatic – material interpreted as human or other omnivorous coprolite, and amorphous organic matter. Rubified particles are common to abundant (Fig. 8). The rubified particles examined did not contain straw moulds.

Postdepositional pedofeatures include rare calcite hypocoatings and rims around mineral grains, and local replacement of yellowish (phosphatic) groundmass of (inferred) excremental particles with calcite (in S1U). Gypsum infillings are also present, but rare. Anorthic iron oxide nodules and groundmass impregnation are rare in sample S1 but abundant in (stratigraphically lower) sample S1U (size range: 1593–249 μm).

Abundance of burning residues suggests that burning had a major role in the formation of Facies SZi. The predominance of inferred straw over wood fuel, however, distinguishes this from other burning-derived facies in the Sagzabad Cluster (e.g. Facies GHiii above). It is possible that straw burning took place in the context of domestic activities, or disposal of post-harvest and/or other residues. Shell, bone and faecal matter also resulted from the accumulation of domestic waste, perhaps near houses or at a dump. Nonetheless, structural indications for the presence of a clearly demarcated palaeofloor (e.g. evidence of trampling) are lacking in this facies.

4.3.2. Facies SZii: gravely loam with abundant human inputs

This facies is represented by sample S-160, from the lower part of Trench 14 (Fig. 3). Texturally, it is very poorly sorted clayey sandy silt with trimodal distribution (C.V: 145.7 – the second highest in the sample set; mean grain diameter: 115.1 μm; Table 2, Figs. 4 and 5). These textural features differentiate this facies from other sediments of Tepe Sagzabad quite clearly.

In thin section, facies SZii is markedly heterogeneous, with open porphyric c/f-related distribution (Table 3). Microrstructure is massive, with occasional fissures and partly filled bioturbation channels (5–10%). About 2.5–25% of mineral grains are affected by pellicular and other forms of alteration, with deposition of iron and manganese oxides in fissures of mafic minerals (alteration class 1 *sensu* Stoops, 2003). Some mineral grains show evidence of heating.

Human and other biogenic inputs are abundant and notably diverse – the most diverse in the Sagzabad Cluster sample set. They comprise abundant plant-derived particles, including charcoal, partly decomposed plant tissue and desiccated plant remains. Less frequent content includes dark brown particles of amorphous organic matter (rare), burned herbivorous dung, phosphatic coprolites, bone fragments (up to 10,256 μm) and angular, rubified particles with straw moulds, interpreted as fragments of straw-tempered brick, plaster or ceramics. Postdepositional

pedofeatures include anorthic iron oxide nodules (161–289 μm) and coatings.

The very high content in plant remains, herbivore dung and other excrement-derived phosphatic materials reflects extensive utilization of domestic animal excrement by Sagzabad's Bronze Age inhabitants. Dung may have been used as fuel, fertilizer and building material, as elsewhere in the ancient Near East (e.g. Shahack-Gross, 2011). Until only two decades ago, dung was used as an expedient hearth and oven fuel in remote, mountainous parts of Iran. If this was also the case in Bronze Age times, Facies SZii may have been deposited at or near a domestic setting – an inference congruent with the relative abundance and diversity of other plant and animal remains. An alternative formative process may have been the (seasonal ?) burning of stable floors. Whatever its origins, the content and some structural aspects of this facies are quite similar to village palaeofloor deposits identified at other prehistoric Iranian settlements (e.g. Tepe Sialk: Kourampas et al., 2013); this facies, however lacks, the particle orientation and laminated microstructure typical of the latter palaeofloors.

4.3.3. *Facies SZiii: muddy loam with abundant domestic residues*

This facies is represented by sample S2, from the lower parts of Trench 14 (Fig. 3). Texturally, this sediment is unimodal, poorly sorted silty clay, similar to facies SZi (Table 2, Figs. 4 and 5).

In thin section, facies SZiii is heterogeneous loam with double space to open porphyric c/f-related distribution (Table 3). The groundmass is brownish and calcium-enriched (as confirmed with SEM analysis: Table 6); gradually it becomes gray and less calcium-rich up-section. Microstructure is complex, with abundant straw mouldic pores (especially in the lower part) and occasional fissures and bioturbation channels, some of which contain loose continuous infilling. Many of the subrounded to rounded mineral grains – mostly feldspars– have been partly dissolved or altered (with pellicular and complex alteration affecting 25–75% of the grains).

Human-induced content is among the richest in the entire sample set. Rubified particles are very abundant; some contain straw moulds and are interpreted as brick, plaster, or pottery fragments (Fig. 6b). A large (7.5 × 4.9 cm) rubified particle with porous internal microstructure may be a fragment of hand-shaped pottery (cf. Macphail and Goldberg, 2010). This particle is much darker on the one side, perhaps as a result of differential heating or absorption of very fine organics (a common occurrence in storage or cooking vessels). Other human inputs include charcoal (less abundant than in overlying S-160) and other burnt plant tissue, burnt herbivorous dung (Fig. 6c), shell fragments and relatively abundant, well rounded fragments of burned and unburned bone (up to 2682 μm). Facies SZiii contains the highest abundance of bone fragments in the Sagzabad Cluster sample set. Postdepositional pedofeatures include relatively abundant anorthic iron oxide nodules (244–138 μm) and very rare calcite hypocoatings.

Abundant bone and burning residues alongside ceramic fragments suggest that facies SZiii received inputs from cooking, consumption and disposal of animal waste, perhaps within a domestic setting.

4.4. *Charcoal content*

Charcoal and black carbon (admixture of charcoal and ash: Stolt and Lindbo, 2010) are important sedimentary markers of past human activity (Courty et al., 1989; Masiello, 2004; Stolt and Lindbo, 2010). Charred plant remains result from relatively low-temperature burning, from <400 to 500 °C (Carbone and Keel, 1985; Boardman and Jones, 1990; Matthews et al., 1997, quoted by Matthews, 2010), to up to about 800 °C (Simpson et al., 2003). Charcoal particles may reflect the use of plant fuel for domestic burning, (for lighting, heating and cooking) and also for manufacturing activities, such as pottery making and metalworking. Quantification of charcoal content in thin section, therefore, may provide insights to human practices that formed the site. Table 4 shows the abundance and dimensions of microscopic charcoal particles in Sagzabad Cluster sediment thin sections.

Table 4
Morphometric analysis of charcoal particles in Sagzabad Cluster sediments.

Sample	NO	Area – mean (μm)	Area – Std (μm)	Area – sum (μm)	Length-mean (μm)	Width-mean (μm)
Ghabristan						
GH1C	42	140,066.97	220,531.24	6,162,946.63	566.86	278.32
GH2-1	172	1,393,253.4	3,547,363.5	239639583	1443.67	785.27
GH2-2	157	1,080,035.5	3,963,209.2	169565579	1132.63	617.81
GH-350	136	752,684.71	2,603,558.5	102365121	1050.02	498.01
Sagzabad						
S1	62	536,176.19	2,838,911.6	33,242,923.7	735.14	312.19
S1U	25	102,042.72	138,740.3	2,551,068.07	531.19	197.62
S2	44	285,060.7	419,114.76	12,542,670.8	817.78	334.49
S-160	104	166,343.02	308,093.54	17,299,674.6	686.9	232.21
Zagheh						
Z1U	11	132,512.29	93,874.4	1,457,635.24	605.14	300.99
Z-100	38	133,000.74	308,815.25	5,054,028.25	497.22	271.21
ZUR	9	379,229.27	571,319.86	3,413,063.43	781.26	503.87

4.4.1. *Zagheh*

At Zagheh, charcoal is comparatively rare (lower than 38 counts per section: Table 4); Z-100 is the only sample with a notable charcoal abundance. This scarcity probably reflects the provenience of most bulk samples from Zagheh in loams resulting from disintegrated plinths (as inferred through thin section micromorphology: facies Ziii, above): plinths made from fine grained alluvia in the periphery of the settlement were probably less likely to have included large charcoal inputs.

4.4.2. *Ghabristan*

The most frequent and largest charcoal particles occur at Tepe Ghabristan (samples Gh2-1, Gh2-2 and Gh-350: Table 4). Almost all charcoal particles are woody; charred particles of fibrous (herbaceous – probably straw) tissue are very rare. In view of the archaeological evidence for manufacturing activity

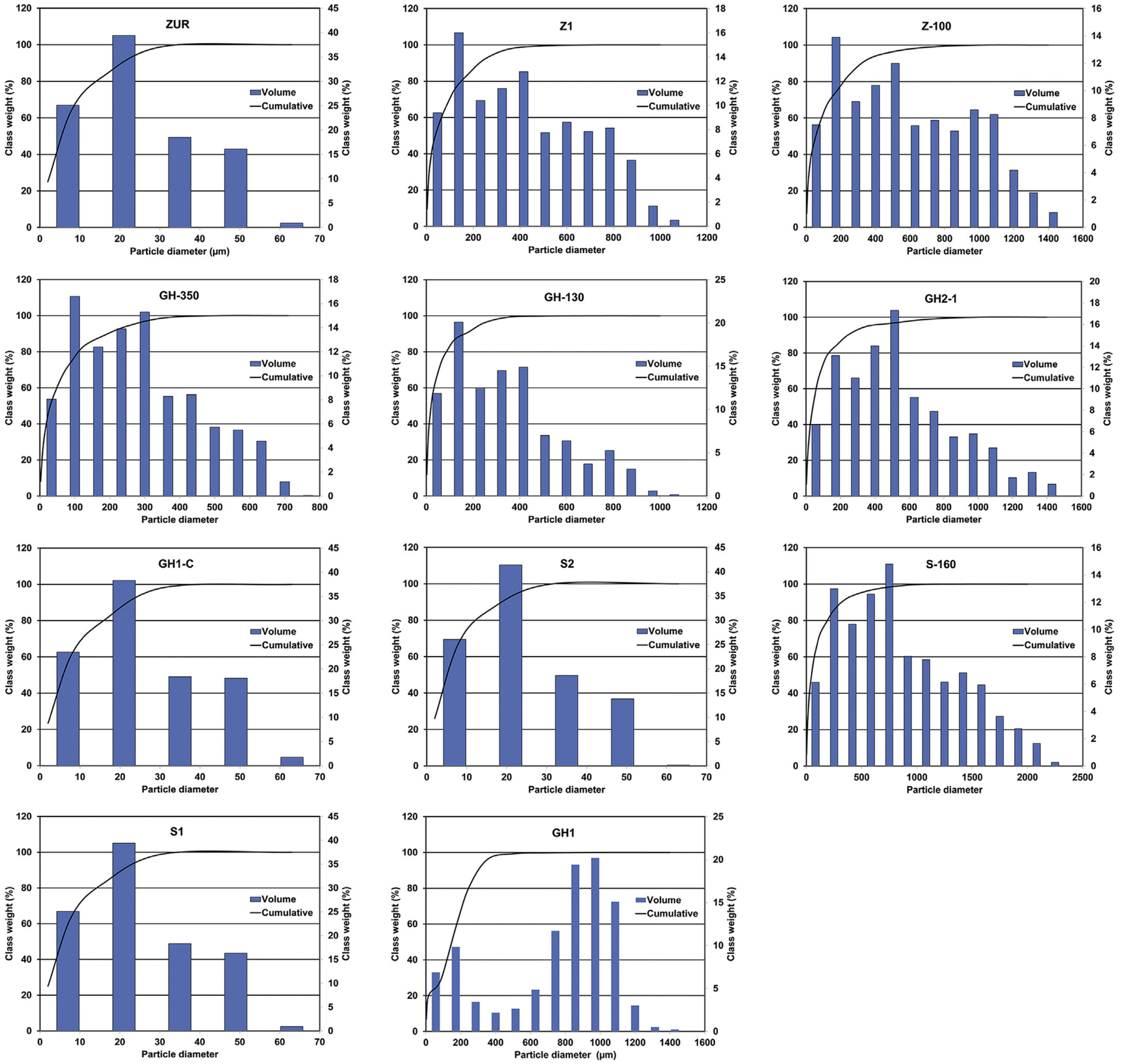

Fig. 4. Grain size distribution of Sagzabad Cluster sediments.

(pottery making) in the southern section of Tepe Ghabristan, where the samples originated (Fazeli et al., 2005), the (apparent) predominance of woody fuel may suggest that the main pyrotechnic activities in the sampled layers involved high-temperature burning, in pottery making kilns. This suggestion is, of course, tentative, as wood may have also been used as a domestic fuel.

Sample Gh1-C, however, contains markedly less charcoal than the rest of the Ghabristan sample set. This corroborates other (micromorphological) evidence that Gh1-C may represent the earliest post-abandonment deposits, resulting from weathering of deserted settlement structures (facies GHii above). Charcoal in this deposit, therefore, may have been reworked from earlier surface hearths, dumps and other primary contexts.

4.4.3. Sagzabad

Tepe Sagzabad deposits (most notably sample S-160) contain the second highest abundance of charcoal in the sample set. By contrast with Ghabristan, most charcoal particles in the Saqzabad sections were derived from herbaceous plant tissue, whereas wood charcoal is rare. This may reflect low-temperature burning of expedient fuel, perhaps in domestic contexts, or burning associated with agricultural and animal herding activities (e.g. burning of post-harvest residues or seasonal burning of stable

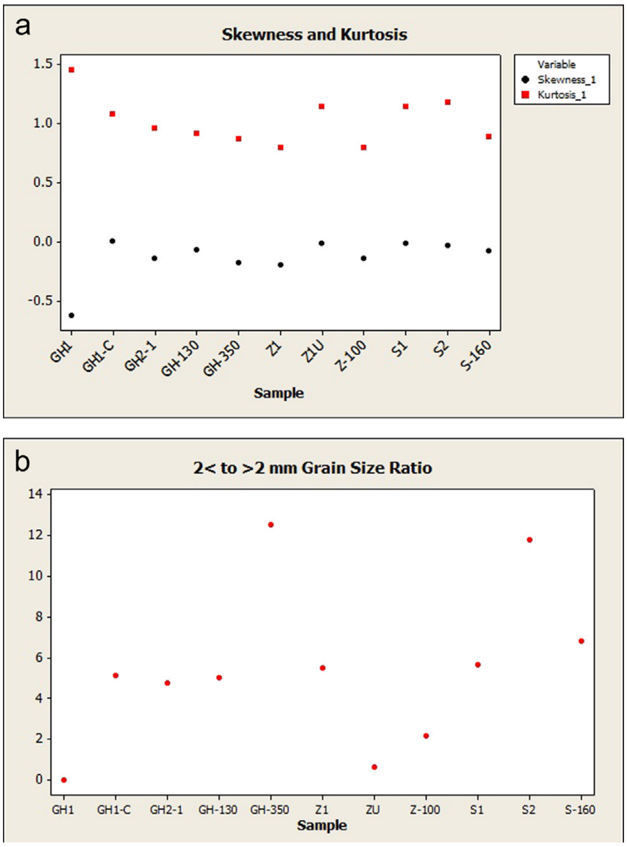

Fig. 5. a) Skewness and kurtosis and, b) fine (>2 mm) to coarse (<2 mm) ratio in Sagzabad Cluster sediments.

floors). The dispersed character of charcoal particles in the sediment matrix, however, is an indication of reworking/redeposition and/or postdepositional mixing of the sediment by soil fauna.

4.5. *Rubified particles*

In the archaeological context of the Sagzabad Cluster sediments, the main source of rubified particles was human-induced burning. As with charcoal particles, therefore, the frequency of rubified particles largely reflects the relative intensity of human activity and the function(s) of sampled sites.

Rubified particle content co-varies with charcoal at all sites (Fig. 8), suggesting that both inputs were derived from the same burning processes, which, at Ghabristan, probably included pottery (and, based on archaeological evidence, metal) artefact making (Fig. 9). This correlation is best expressed at Sagzabad facies SZi and SZiii (samples S-160 and S2), the sediments richest in rubified particles. This accords with other lines of evidence (micromorphology; grain size peak at 5–30 μm, reflecting the presence of calcareous ash) suggesting a strong anthropogenic input of domestic (?) burning byproducts at that particular site. Sample Z-100, at Zagheh is also rich in rubified particles.

4.6. *Organic matter analysis*

Organic matter (OM) content often is relatively low in soils and sediments of arid regions (Gerasimova and Lebedeva-Verba, 2010). In the archaeological context of the sampled sediments, co-depositional enrichment in organic matter was probably due to human activity. An exception to this is sample Z-100 from Zagheh (Table 5, Fig. 9), where much of the high OM value is due to root, soil fauna excrement and other postdepositional organic inputs (facies Zii above).

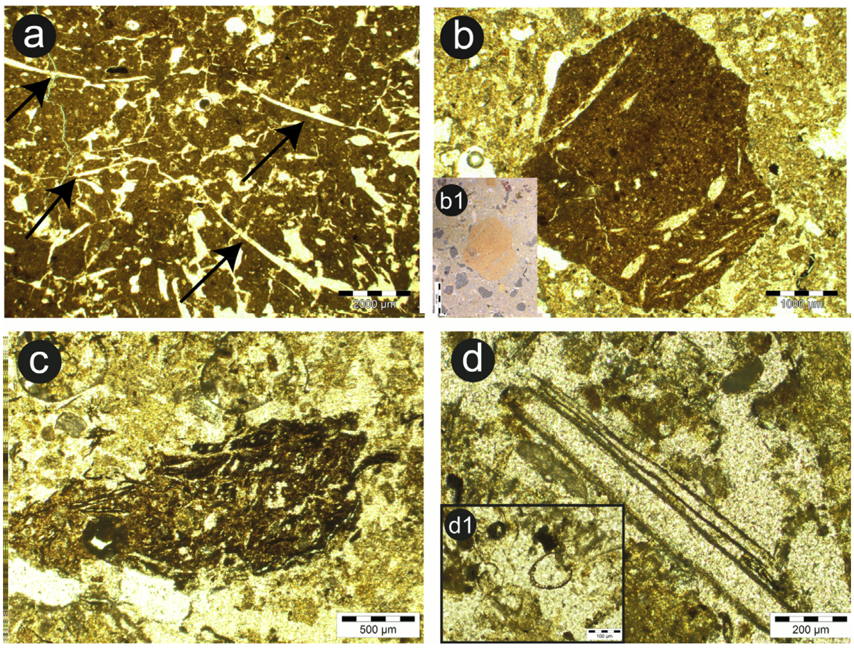

Fig. 6. a) Porous muddy loam with large elongate (probable straw moulds – arrows) and smaller, bioturbation pores, interpreted as resulting from the disintegration and bioturbation of straw-tempered plinths: sample ZUR, Zagheh Tell, PPL. b) Straw-mouldic pores in rubified particle, interpreted as baked brick or ceramic fragment: sample S2; Sagzabad Tell. (PPL; OIL in frame). c) Particle with organic-phosphatic matrix and fibrous plant remains, interpreted as herbivore dung: sample S2; Sagzabad Tell (PPL). d) Desiccated plant remains – possibly cereal: sample S2; Sagzabad Tell (PPL).

Table 5
Organic matter (OM) content of the sampled sediments, (measured with loss-on-ignition).

Sample	Sediment colour	OM (LOI) (%)	
Zagheh			
Z1	10YR 3/2 very dark grayish brown	3.77	Cultural
Z-100	10YR 4/2 dark grayish brown	7.62	Cultural
Z1U	10YR 6/4 light yellowish brown	4.44	Cultural
Sagzabad			
S-160	10YR 5/3 brown	6.74	Cultural
S2	7.5YR 6/3 light brown	4.56	Cultural
S1	7.5YR 6/4 light brown	4.85	Cultural
Ghabristan			
GH2-1	10YR 6/1 Gray	4.15	Cultural
GH-130	7.5YR 6/3 light brown	2.61	Cultural
GH1-C	7.5YR 6/3 light brown	2.87	Cultural
GH1	7.5YR 6/3 light brown	1.17	Natural
GH-350	10YR 6/2 light brownish gray	2.91	Cultural

At Zagheh, samples Z1U and Z1, from plinth collapse facies Ziii at the top of the settlement's cultural layers, contain moderate amounts of organic matter. This contrasts with micromorphological observations that show low organic content in these plinth collapse deposits (Table 3).

At Ghabristan, low OM values in sample GH1 (post-occupation channel fill: Fig. 3) reflect the fluvial origins of the sandy sediment. In GH1-C, located under the GH1, OM is low, in keeping with thin section evidence. In GH-350, moderate values of OM perhaps reflect extensive burning (congruent with the high ash content of this layer, as identified in thin sections). In GH2-1, high OM values (4.14%) probably reflect the abundance of charcoal in this burning residues-rich sediment. High OM values in samples S-160, S1 and S2 from Sagzabad (more than 4.5%), result from herbivore dung, desiccated and charred plant tissue, amorphous organics and other inputs from ancient human activities.

4.7. Elemental analysis

Table 6 shows the mean elemental composition of selected areas of sediment micromass in the Sagzabad Cluster sample set. Iron (Fe) ranges from over 2% (samples GH1-C, Z1U, S1) to less than 1% (samples GH2-1, GH2-2), in agreement with micromorphological evidence (Fig. 7l). Calcium (Ca) is relatively high throughout, ranging from over 4.70% (GH2-1, GH1-C and S1U) to about 3.70% (Z-100 and S-160).

Phosphorous (P), an element commonly enriched in 'cultural' layers (Karkanas and Goldberg, 2010; Stoops et al., 2010) is highest in S1U, followed by GH1-C and Z1U (in the latter at much lower values, less than 50% of the S1U phosphorous concentration). These high phosphorous values may reflect dung inputs in the micromass (as also suggested by micromorphological analysis).

High amounts of sulfur (S) are present in samples that contain diagenetic gypsum (as confirmed from micromorphological analysis: Gh2-1, GH2-2, GH-350 and, especially, ZUR).

Silica (Si) is high in most samples. Relatively low silica values in samples Gh2-1 and GH2-2 from Ghabristan are noteworthy (Table 6). These samples are also enriched in carbonate, in keeping with their ashy composition. Low silica values probably reflect the relatively low content of these sediments in siliclastic grains (as observed in thin sections).

5. Discussion: archaeological sediments of the Sagzabad Cluster

Sediments from the settlements of the Sagzabad Cluster exhibit poorly sorted, bimodal/trimodal textural signatures. Since the ultimate provenance of building materials was local alluvial sediment from around the sites, some of these textural signatures could reflect the depositional conditions of this alluvial fan setting. As suggested by micromorphological evidence, however, the dominant driver of sediment deposition was human activity, which contributed the bulk of material (as in ash and burning residue layers) or concentrated and redistributed fine-grained alluvial sediments from elsewhere (as in the copious quantities of mud plinths). Textural signatures such as a significant coarse (>2 mm) fraction, poor sorting, bimodal or trimodal grain size distributions and distinct peaks in the 5–30 μm range (for ash-rich sediments) are markers of predominantly human-induced deposition.

Grouping sediments of the sample set into facies permits a comparison of basic textural and structural features and the identification of recurrent associations of the latter. Each of the nine identified facies embodies a distinct array of depositional processes, reflecting site function, specific location within the ancient settlement fabric and geomorphic setting. All identified facies have been shaped by human action – predominantly burning, food consumption, house building and waste disposal – in conjunction with colluvial and alluvial processes (surface wash and overbank deposition).

Restricted scale of sampling and incomplete stratigraphic control limit the range of inferences permitted by this sedimentary evidence. However, this pilot study enables us to draw a provisional

Table 6
Mean elemental composition of sediment micromass.

Sample	C (%)	O (%)	Na (%)	Mg (%)	Al (%)	Si (%)	K (%)	P (%)	Ca (%)	Ti (%)	Fe (%)	Mn (%)	S (%)	Cl (%)
Ghabristan														
GH1-C	33.06	40.9	0.36	0.87	3.8	11.99	1.44	0.58	4.77	0.2	2.31		0.11	
GH2-1	52.12	33.83	0.21	0.33	1.02	4.18	0.44	0.21	4.83	0.2	0.68		2.11	0.09
GH2-2	53.1	34.1	0.21	0.38	1.05	4.14	0.48	0.19	4.12	0.07	0.66		1.512	0.09
GH-350	44.6	35.8	0.35	0.57	2.17	8.6	1.02	0.32	4.37	0.14	1.32		0.919	0.09
Zagheh														
Z1U	32.04	42.44	0.45	0.85	3.99	11.97	1.54	0.45	4.03	0.21	2.21	0.25		
Z-100	42.5	37.54	0.36	0.61	2.58	9.84	0.94	0.27	3.7	0.14	1.58			0.07
ZUR	39.94	37.39	0.37	0.64	3.16	10.53	1.26	0.25	4.1	0.21	1.79	0.46	4.8	
Sagzabad														
S-160	41.29	38.7	0.31	0.74	2.42	9.81	1.06	0.26	3.77	0.15	1.52			
S1	36.04	41.41	0.35	0.83	2.85	10.83	1.22	0.23	3.83	0.16	2.28		0.11	0.14
S2	40.69	39.29	0.34	0.9	2.55	9.35	1.08	0.24	3.85	0.14	1.58		0.08	
S1 U	36.24	40.83	0.36	0.83	3.01	9.8	1.3	1.05	4.76	0.32	1.66		0.77	0.09

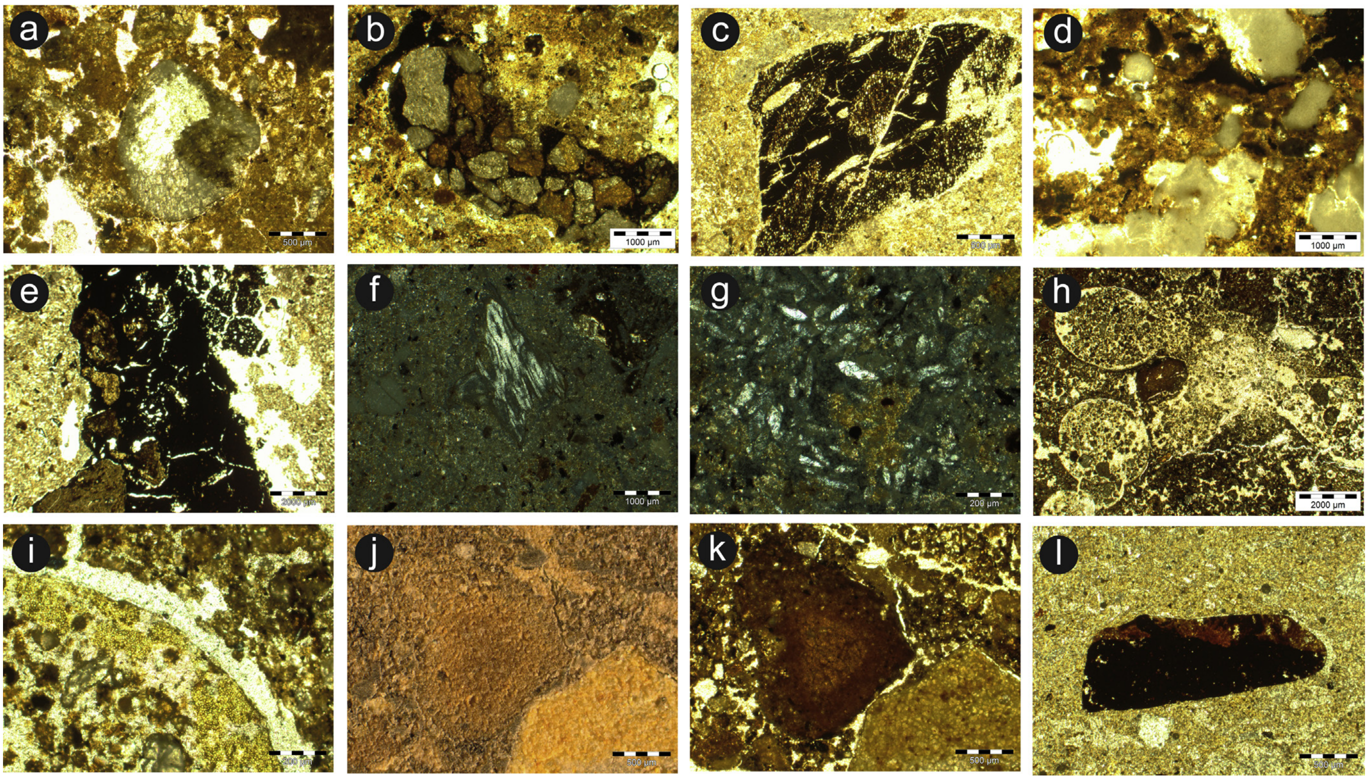

Fig. 7. a) Altered rock fragment: sample GH1-C, Ghabristan Tell (PPL). b) Compacted, heat-altered grains in opaque organic matrix. This particle may have been derived from the lining of a cooking vessel or oven, or from plaster exposed to intense burning. Sample GH-350: Ghabristan Tell, PPL. c) Charcoal particle: sample GH-350, Ghabristan Tell, PPL. d) Microcrystalline gypsum nodules grey infilling and replacing ash deposits: sample GH-350, Ghsbristan Tell, (PPL, XPL). e) Organics-rich, dung-based (?) material, possibly derived from daub or oven lining: sample GH2-2, Ghabristan Tell, PPL. f) Angular bone fragment: sample GH2-2; Ghabristan Tell, XPL. g) Mosaic of lenticular gypsum crystals: sample GH2-1, Ghabristan Tell, XPL. h) Invertebrate burrows with granular infill: sample Z-100, Zagheh Tell, PPL. i) Yellow, phosphatic (?) particle of probable excremental origin: sample Z-100, Zagheh Tell, PPL. j) Rubified particle (centre): sample Z-100, Zagheh Tell, OIL. l) Same as (k), PPL. l) Fe nodule: sample GH-350, ppl. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

sketch of (some) human-induced processes of sediment deposition recurrent in the Sagzabad Cluster.

5.1. Masonry degradation deposits

Deposits resulting from the degradation of masonry elements are characterised by their fine-grained texture, relative scarcity of coarser grains and rare burning residues (e.g. Zagheh facies Ziii). Variations of these deposits probably contribute the greatest volume of sediment occurring at the settlement sites. As in many other Near Eastern settlements (Matthews et al., 1997; Shahack-Gross and Finkelstein, 2008; Friesem et al., 2011; Kourampas et al., 2013), the bulk of these sediments resulted from disintegration of unbaked straw-tempered plinths.

At the Sagzabad Cluster, the textural characters of these sediments approximate those of fine-grained distal fan and overbank deposits and are very similar to those of pre-occupation sediments in the area (Maghsoudi et al., 2013). We thus infer that plinth-building materials were derived from alluvial mud in the immediate environs of the sites. A similarly close provenience of plinth clays has been documented at other ancient Near Eastern settlements (e.g. south-west of Baghdad: Stoops and Nijs, 1986).

5.2. Sediments with burning residues

Such deposits are very common in the Sagzabad Cluster, as in virtually any earlier human settlement (c.f. Matthews et al., 1997; Shahack-Gross and Finkelstein, 2008; Kourampas et al., 2013, for comparable Near Eastern/Iranian deposits). These sediments are especially variable, with three distinct facies groups identified in the small sample set of this study. This variability comes as no surprise, given the very broad range of pyrotechnic practices in earlier societies.

Ash deposits, representing accumulated residues from thorough, high-temperature burning, constitute a class of their own. Alongside their well known and widely reported micromorphological characteristics (Courty et al., 1989; Canti, 2003; Simpson et al., 2003; and Macphail, 2006), ash deposits have distinctive textural signatures, with grainsize distribution peaks in the 5–30 μm range. Such peaks are also present, but less well pronounced, in mixed but ash-rich sediments. The latter are also characterised by their markedly poor sorting and bimodal or trimodal grain size distribution.

In addition, it is possible to identify distinct associations of burning residues and other particles, each reflecting different fuel sources, burning temperatures and social/technological contexts of burning. The two most readily distinguishable associations in the limited sample set of this study are:

a) *Straw ± dung fuel*, mainly associated with bone, and other possible food residues, and seemingly resulting from low-temperature burning and/or expedient fuel use in a domestic context (e.g. facies SZii in Sagzabad);
b) *Wood fuel*, which is much more common. Locally, it occurs in association with bone splinters and fragments of possible storage or cooking vessels, in what may have been a domestic

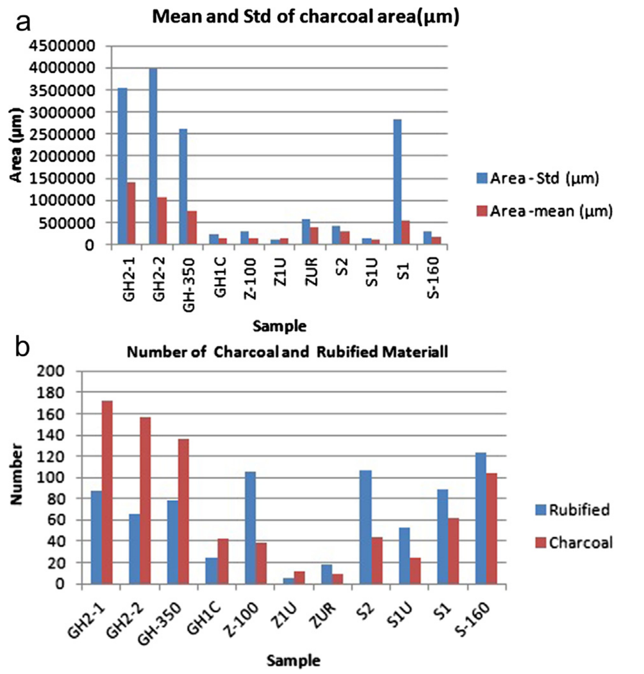

Fig. 8. a) Relative frequency of charcoal and rubified particles. b) Mean size and standard deviation of charcoal particles in Sagzabad Cluster sediments.

context (e.g. facies SZiii at Sagzabad). Elsewhere, wood charcoal occurs in association with brick or ceramic fragments in probable manufacturing contexts that may have involved high-temperature burning (e.g. facies Zii at Zagheh).

5.3. *Fuel sources and sediment diagenesis*

Although no taxonomic identification of fuel remains was attempted in this study, the preliminary evidence outlined here clearly indicates that ancient inhabitants of the Sagzabad Cluster made systematic use of diverse fuel sources. This (sketchy) picture is congruent with earlier analyses of plant residues and charcoal from the Late Neolithic layers of Tepe Zagheh. Earlier workers (Molla Salehi et al., 2006; Shirazi et al., 2006) noted abundant remains from four kinds of plant communities, hygrophilous; shrub-steppic; mountainous; and steppe-forest, with a dominance of the salt cedar taxa *Tamarix* sp. (86.8%) and *Salix* cf *alba* (8.8%). These

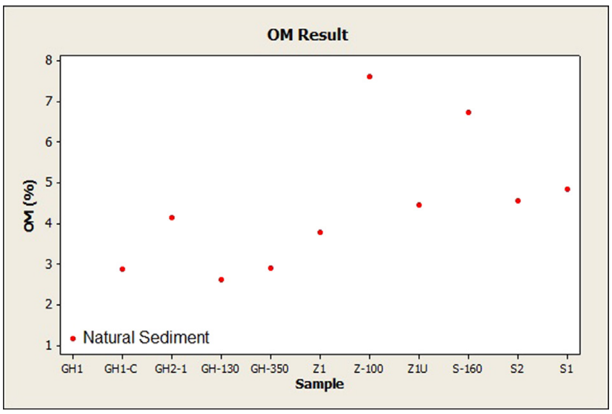

Fig. 9. Organic matter content of Sagzabad Cluster sediments (measured with loss-on-ignition).

plants suggest wetter environmental conditions with intermediate moisture and availability of soil salts (saline environments are favorable to *Tamarix*, which typically occupies loamy, organics-rich soils with intermediate moisture, high water tables, and little erosion: Brotherson and Winkel, 1986).

As noted, certain types of fuel may have had a notable effect on sediment diagenesis. In the small sample set of this study, extensive gypsum neoformation, with lenticular crystals, is clearly associated with ash deposits that may have been generated from *Tamarix* burning. In the absence of taxonomic identifications of charcoal, however, this inference remains tenuous.

6. Conclusions

The prehistoric settlements of the Sagzabad Cluster, in the semiarid Qazvin Plain, were established on the toes of the coalescent Hajiarab fan system to ensure access to dependable fresh water resources, variable landscapes and ecotones, and appropriate soils and sediments for cultivation, pottery and plinth-making. Channel migration and alluvial sedimentation had marked impacts on settlement preservation.

Settlement sediments resulted from the interplay between alluvial deposition in a coalescent fan system and human practices at the settlement sites. Nine identified sediment facies preserve evidence for a range of ancient human practices including wood, straw and dung fuel utilization, deposition of various kinds of domestic and livestock waste and, possibly, systematic manufacturing (high-temperature burning in possible brick or pottery kilns and/or metallurgical workshops). Salt cedar (*Tamarix* sp) fuel utilization may have initiated distinctive diagenetic pathways, with the crystallization of gypsum from *Tamarix* ash.

Further sedimentological and geochronological studies have the potential to enrich the preliminary insights of this work and refine our understanding of settlement emergence and decline, past practices of habitation, and the ecological links and feedbacks between prehistoric settlements and the landscapes and ecosystems on the Iranian Plateau.

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